EFFECTS OF IMPACT METAMORPHISM IN LIMESTONES OF THE STEINHEIM CRATER - THE X-RAY DIFFRACTION STUDY. R. Skála[1] and P. Jakeš[2], [1]Dept. of Mineralogy and Petrology, National Museum, CZ-11579 Praha 1, Czech Republic, e-mail: ais@nm.anet.cz, [2]Inst. of Geochemistry., Faculty of Science, Charles University, Albertov 6, CZ-12843 Praha 2, Czech Republic, e-mail: jakes@prfdec.natur.cuni.cz.

Introduction

The aim of the study is to show effects of impact metamorphism in carbonate sedimentary rock sequences of the Steinheim Crater as revealed in X-ray powder diffraction patterns.

The Steinheim Basin in Southern Germany (latitude 48°02'N, longitude 10°04'E) lies in carbonate sedimentary lithologies of the Swabian Alb. It is world renowned impact structure due to the first description of shatter cones in the central feature of this structure. Detail data on history and geology of the basin are given in [1]. The diameter of the structure varies between 3.8 km and 3.1 km. Central feature of the crater is about 900 m in diameter and roughly 50 m high. Rocks occurring in the crater vicinity are Upper Malmian limestones and marls. Limestones and marls of Lower Malm and clays, limestones, and sandstones of Dogger are found in the central hill.

Limestones that are found both within and outside the crater are generally very fine grained. The use of optical microscopy, applied earlier in studies on quartz bearing materials from many impact structures, does not allow to recognize impact induced features undoubtedly. On the other hand, powder diffraction patterns can clearly record both dynamic and static pressure induced comminution in many types of target material as it is described in e.g. [2].

We have chosen unshocked Upper Malmian limestone from Solenhofen as a reference material and a country rock containing a shatter cones found near Steinheim on the slopes of the crater central feature as a typical representative of shocked lithology.

Experimental

Our attention was focused mainly on profile shapes which are generally very sensitive to any change in size of crystallites and/or lattice strain. Unit cell parameters as a measure of shift of position of individual reflections were also refined.

Rock samples were prepared in a routine way for the powder diffraction study. Chips or powder provided by micro-drill were grounded in an agate mortar together with alcohol. This suspension was poured on glass flat sample holder and slightly heated to evaporate alcohol.

Diffraction data were collected using HZG 4 goniometer in Bragg-Brentano reflecting geometry equipped with proportional counter with pulse height discrimination and primary Soller slits. Measuring radius of the goniometer was set to 250 mm. Copper nickel-filtered radiation was utilized (TuR M62 high voltage generator operated at 30 kV and 30 mA). Range of step-scanning was 20 to 52 °2q with step size 0.05 °2q and exposure 10 seconds per one step.

Angular positions of individual reflections and their respective FWHM's were calculated using program package ZDS assuming profile shape of reflections is close to Pearson VII function. Indexing of refined reflections was based on data generated by program LAZY PULVERIX from crystal structures taken from ICSD database. Unit cell parameters were then refined by appropriate module of ZDS system.

Results of the study

The most apparent feature of all collected powder patterns is increasing deformation of reflections shape with more violent expected pressure comminution. Generally, the higher expected shock metamorphism the lower and broader reflection are observed. Another effect easily observable at the patterns is progressive disappearance of reflection 006 at about 31.5 °2q CuKa and significant decrease of possibility to distinguish reflection 024 in triplet between roughly 47 and 49 °2q CuKa.

FWHM has appeared to be a good and sensitive indicator of lattice imperfections of any origin [2] and this fact has been approved for naturally shocked quartz from the Barrinegr crater in Arizona by [3]. Except general trend of increase of reflection breadth with increasing diffraction angle as expressed by Caglioti *et al.* [4] formula

$$(\mathrm{FWHM})^2 = W + V \tan q + U \tan^2 q ,$$

where U, V, W are refinable parameters of quadratic regression and q is halved diffraction angle, there is a strong tendency of increase of absolute FWHM value for particular reflection in certain powder pattern with higher expected shock load. This tendency is fully compatible with observations for quartz published in [3]. Comparison of reflection breadth depending on diffraction angle for three studied samples is plotted in Fig.1.

Unit-cell parameters of trigonal calcite cell in hexagonal obverse setting differ slightly in case of cell dimension a; length of cell edge c is more variable (see Table). Nevertheless, overall differences are not so pronounced as in case of FWHM's. Therefore, calculated cell volumes and densities assuming pure calcite composition for all samples do not

Table: *Unit cell parameters and volumes, and calculated densities for the limestone samples studied.*

	(1)	(2)	(3)
a (Å)	4.9783(5)	4.984(2)	4.990(9)
c (Å)	17.023(3)	17.05(2)	16.95(4)
V (Å^3)	365.4(1)	366.8(5)	366(2)
r (g.cm^{-3})	2.7291(7)	2.719(4)	2.73(1)

Samples description: (1) unshocked Solenhofen lithographic limestone, (2) limestone from a point about 1.5 cm below shatter cone surface with small admixture of quartz, (3) thin film from the shatter cone surface (traces of quartz recorded). Samples (2) and (3) represent shocked lithology.

differ significantly and limited set of measurements does not allow to characterize these variables with respect to expected pressure load properly. Another problem with cell dimensions concerns their accuracy and mutual comparability and arises from rather small number of reflections available in the measured range which is further lowered due to disappearance of 006 reflection and increasing overlap of 024 and 018 reflections as the expected pressure comminution increases.

Discussion

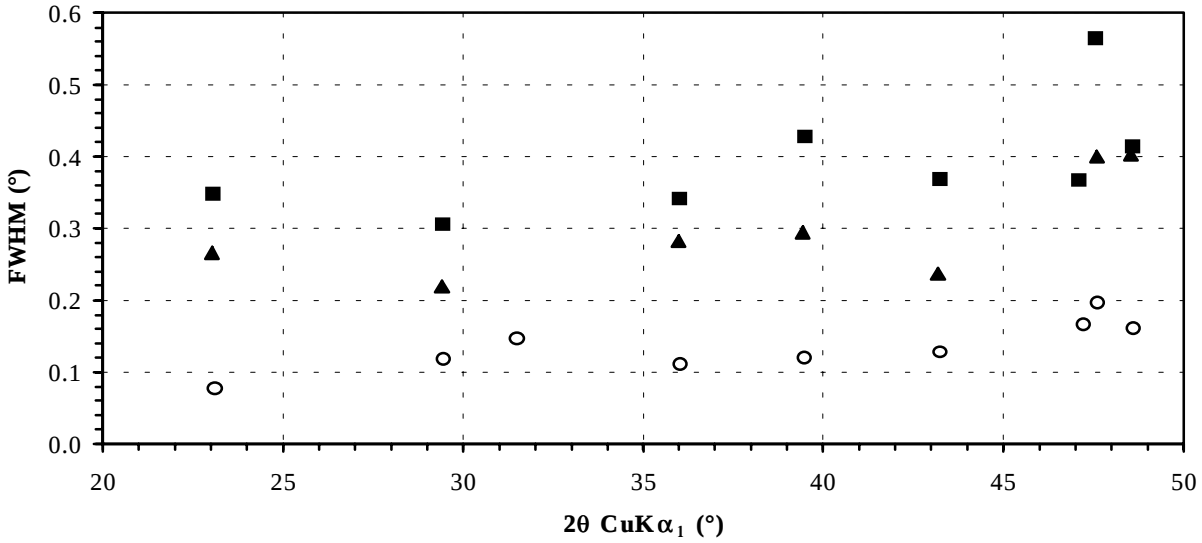

Fig. 1. Comparison of reflection breadths (FWHM in °) depending on diffraction angle. Open circles represent unshocked Solenhofen limestone, solid squares stand for shocked material sampled below the shatter cone surface, whereas solid triangles represent limestone material of the shatter cone surface.

When we accept a thought that reflections become broader with increasing shock pressure load, it is possible to find amorphized (with respect to X-rays) carbonate material in samples which probably underwent heavy shock wave treatment. Such type of material could perhaps be found as an uppermost part of thin coatings on shatter cones. However, serious problems were met when attempts to separate this material were undertaken.

When Caglioti *et al*. formula will be applied for fitting of individual curves FWHM *vs*. 2q at a larger data set from one or even several localities, correlation of possible pressure history will probably be possible on a statistical basis.

Diffraction patterns of calcite do not allow to calculate comparable sets of unit cell parameters (at least in the range studied in this work) as it is possible for e.g. quartz due chiefly to varying number of reflections in individual powder patterns. So, application of these values for direct comparison of individual samples with respect to variable pressure comminution seems to be rather limited.

Anyway, X-ray powder diffraction has proved its great usefulness for research of this type of target material and mainly study of reflection broadening has clearly indicated the way how strong shock induced effects can be found in calcite bearing material.

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References

[1] Reiff W. (1977) In Roddy *et al*. Eds.: Impact and Explosion Cratering. Pergamon Press, 309-320, [2], Klug H.P. and Alexander L.E. (1974) X-ray Diffraction Procedures, 2nd ed., Wiley, 966 pp., [3] Skála R. (1996) *Meteoritics and Planetary Science*, **31**, Supplement A130-A131, [4] Caglioti *et al*. (1958) *Nuclear Instruments and Methods*, **35**, 223-228.